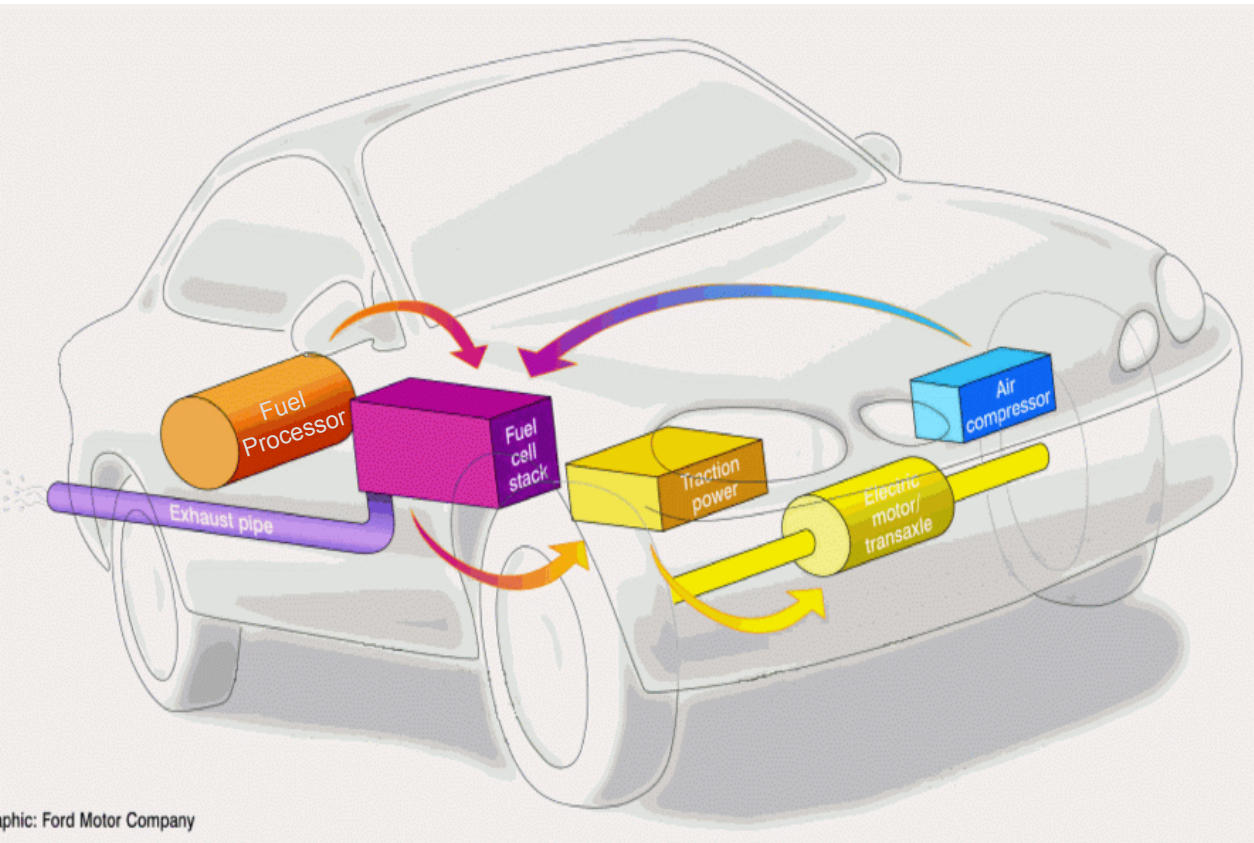
# Fuel Cell Systems




***Sensors***
***Air Management***
***Benchmarking***
***Modeling***

***Patrick Davis***

# Targets and Status

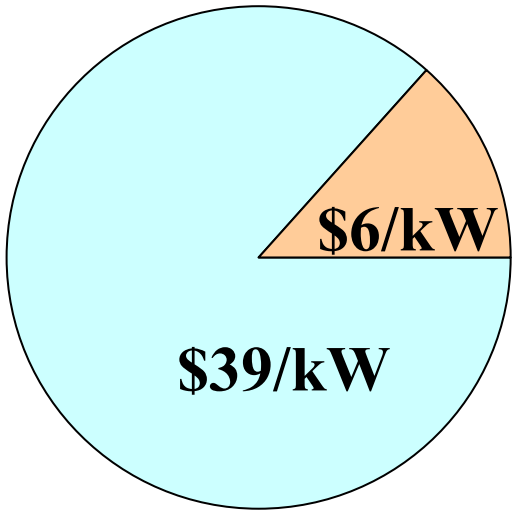
50 kWe (net) Integrated Fuel Cell Power System

| Characteristics | Units | 2003 status | 2005 | 2010 |
|---|---|---|---|---|
| Operating on Tier 2 gasoline containing 30 ppm sulfur, average | | | | |
| Power density | W/L | 140 | 250 | 325 |
| Cost | $/kW | 325 | 125 | 45 |
| Durability | Hours | 1000 | 2000 | 5000 |
| Operating on direct hydrogen | | | | |
| Power density (w/o H2 stor) | W/L | 400 | 500 | 650 |
| Cost (including H2 storage) | $/kW | 275 | 125 | 45 |
| Durability | Hours | 1000 | 2000 | 5000 |

# Projects
## Fuel Cell Power Systems Analysis

| | |
|---|---|
| • Fuel Cell Systems Analysis | ANL |
| • Fuel Cell Vehicle Systems Analysis | NREL |
| • Cost Analyses of Fuel Cell Stacks/ Systems | TIAX |
| • DFMA Cost Estimates of Fuel Cell/ Reformer Systems at Low, Medium, & High Production Rates | Directed Technologies, Inc. |
| • Assessment of Fuel Cell Auxiliary Power Systems for On Road Transportation Applications | TIAX |
| • Precious Metal Availability & Cost Analysis for PEMFC Commercialization | TIAX |

# Barriers
## Air Management Subsystem




Air Management
(50-kW System)

Fuel Cell Power System
$45/kW

NEEDS

- Minimize parasitic power consumption
- Reduce weight
- Improve efficiency
- Integrate with fuel cell and fuel processor
- Reduce cost

# Status and Proposed Targets

## Compressor/Expander for Transportation Fuel Cell System

| Characteristics | Units | 2003 status | 2005 | 2010 |
|---|---|---|---|---|
| 50-kW Unit | | | | |
| Efficiency at Full Flow | % | <70 (C), <80 (E) | 80 | 80 |
| Volume | L | 10-12 | 8-11 | 8-11 |
| Turndown Ratio | | 5 | 10-15 | 10-15 |
| Cost | $ | 600 | 400 | 300 |
| 80-kW Unit | | | | |
| Efficiency at Full Flow | % | - | - | 80 |
| Volume | L | - | - | 15 |
| Turndown Ratio | | - | - | 15 |
| Cost | $ | - | - | 400 |

# Projects
## Air Management

| | |
|---|---|
| • Turbocompressor for PEM Fuel Cells | Honeywell |
| • Hybrid Compressor/Expander Module | TIAX |
| • Motor Blower Technology for Fuel Cell Automotive Power Systems | UTC |
| • High-Efficiency, Integrated Compressor/Expander Based on Torroidal Intersecting Vane | Mechanology, LLC |

# Discussion Points

- Develop compressor/expander units for direct hydrogen systems.
- Need exists for compressor/ expander motor unit for fuel cells larger than 50kW.
- Will larger compressor/expander units be scalable from current work?
- How large a compressor/ expander unit will ultimately be needed?

# Sensor Types

- CO
- $H_2$ in Fuel Processor Output
- $H_2$ in Ambient Air
- Sulfur Compounds ($H_2S$, $SO_2$, organic sulfur)
- Flow Rate of Fuel Processor Output
- Ammonia
- Temperature
- Relative Humidity for Cathode and Anode Gas Streams
- $O_2$ in Fuel Processor and at Cathode Exit
- Differential Pressure in Fuel Cell Stack

# Targets and Status

## Sensors for Automotive Fuel Cell Systems

| Sensor | Op. Temp. | Response Time | Accuracy |
|---|---|---|---|
| CO: | | | |
| 1-100 ppm reformate pre-stack sensor | <150 °C | 0.1-1 sec | 1-10% full scale (fs) |
| 100-1000 ppm CO | 250 °C | 0.1-1 sec | 1-10% fs |
| 0.1-2% CO sensor | 250-800 °C | 0.1-1 sec | 1-10% fs |
| $H_2$ in fuel processor output | 70-150 °C | 0.1-1 sec for 90% response to step change | 1-10% fs |
| $H_2$ in ambient air | -30-80 °C | Under 1 sec | 5% |
| Sulfur compounds | Up to 400 °C | <1 min @ 0.05 ppm | N/A |

# Targets and Status

## Sensors for Hydrogen and Fuel Cell Systems

| Sensor | Op. Temp. | Response Time | Accuracy |
|---|---|---|---|
| CO:<br>1-100 ppm reformate<br>100-1000 ppm CO<br>0.1-2% CO sensor | <br><150 °C<br>250 °C<br>250-800 °C | <br>0.1-1 sec<br>0.1-2 sec<br>0.1-3 sec | <br>1-10% full scale (fs)<br>1-10% fs<br>1-10% fs |
| H2 in processor output | 70-250 °C | 0.1-3 sec for 95% response to step change | 1-10% fs |
| H2 in ambient air | -30-80 °C | Under 1 sec | 5% |

# Sensor Requirements

- Must perform within required ambient and process conditions
- Fast response time
- Acceptable accuracy
- Must conform to size, weight, and cost constraints of automotive applications
- Acceptable lifetime (durability)
- Must measure properties within the required range
- Low Cost

# Sensor Projects

- Carbon Monoxide Sensors for Reformate-Powered Fuel Cells - LANL
- Electrochemical Sensors for PEM Fuel Cell Vehicles LLNL
- Interfacial Stability of Thin Film H2 Sensors - NREL
- Sensors for Automotive Fuel Cell Systems – UTC Fuel Cells
- Micro-Machined Thin Film H2 Gas Sensors - ATMI
- Sensor Development for PEM Fuel Cell Systems – Honeywell
- Gallium Nitride Integrated Gas/ Temperature Sensors for Fuel Cell Systems Monitoring for Hydrogen & Carbon Monoxide – Peterson Ridge LLC
- Robust Fiber-Optic Temperature Sensor for Fuel Cell Monitoring - ORNL

# Discussion Points

- Program focus on component development
- Continued importance of modeling
- Benchmarking will be used to measure progress
- Air management & Sensors will continue to be emphasized